# THE APPLICATION OF AERIAL PHOTOGRAPHY TO URBAN ROAD DEVELOPMENT IN CALABAR MUNICIPALITY

BY

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## DECLARATION

This project is an original work carried out by me under the supervision of Dr. P.S. Akinyeye. To the best of my knowledge no part thereof has been submitted elsewhere for the award of any degree. Rather, all previous researches are acknowledged and referenced.

Sign: ____________________

Ogbeche Ogbor Anthony (Author)

Date: 23/3/2001

## CERTIFICATION

I, the undersign certify that this project is the original work carried out by Mr. Ogbeche Ogbor Anthony of the Department of Geography (Remote Sensing Application Unit), Federal University of Technology, Minna.

Sign: ________________________________

Dr. P.S. Akinyeye (Project Supervisor)

Date: ________________________________

## APPROVAL

This thesis, directed and certified by the Author's Supervisior, has been read, approved and accepted by the undersign in partial fulfillment of the requirements for award of Master of Technology. (M.Tech) degree in Remote Sensing Applications in the Department of Geography, Federal University of Technology, Minna and as meeting the requirements of the Post-Graduate School, Federal University of Technology, Minna.

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# DEDICATION

To the agents of my growth

and

development –

Chief and Mrs. A. O. Ogbeche.

## ACKNOWLEDGEMENTS

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I am highly indebted to my parents - Chief & Mrs. A.O. Ogbeche – and sister –Ofy – who have so often provided the encouragement, support and finances which has lifted my flagging spirits, not minding the cost. In a similar and no little way, I wish to commend the contributions of Ogbene, Mr. and Mrs. A. Ecko, Mr. J. Irek, Engr. F.A. Ogar, Mr. and Mrs. J. Odey, Mario, Chris, Hassan, Husseini, Dr. Tom, Bill, Umar and Saminu.

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For permission to use and publish the aerial photographs of Calabar, acknowledgement is made to the Forestry Commission, Calabar; and officers of the Cartography and Remote sensing department – Mrs. B. Nkor and Mr. E. Ekeng.

Lastly, but no means the least, I wish to register my unreserved appreciation to my *Oga*, Mallam Mohammed Batati, for his overwhelming support and encouragement in this course.

# ABSTRACT

Urban road development, network structure and condition in Calabar Municipality have been studied to verify the application of remote sensing techniques in urban road development, using in particular, aerial photohraphs. Also, the provision of road traffic facilities and feeder roads in the course of urban road development was studied along with network structure and condition. The provision of road traffic facilities and feeder roads are geared towards accommodating the increasing demand for road space, viz.-a-viz. the quality of the city. Where this is not the case the urban road network structure becomes inefficient. The aerial photographs and photomaps over Calabar Municipality, was interpreted to firstly compute the length and volume of roads on the townscape at the times of imagery collection. Furthermore, the graph theory was employed to analyse the road plan efficiency. For the ground truthing , manual measurements and observations were undertaken on the roads within the town in order to identify features' condition and extent. Given the slow rate of road development; the extent of the network is quite low and the structure is complex, with a low degree of accessibility. Also, the provision of road traffic facilities and feeder roads have been inadequate. The result, indicates that remotely sensed data can be applied to urban road development in data collection and proper analysis of such. The processes of the city's growth in relation to irregularity of roads was also considered. It became obvious that proper urban road development could be achieved only if there is adequate and up –to-date data collection on road development within the town such as with the use of remotely sensed data in planning and policy formulation.

## TABLE OF CONTENTS



**CHAPTER 1**



**CHAPTER 2**

**CHAPTER 3**



**CHAPTER 4**

## LIST OF TABLES



## LIST OF FIGURES

# CHAPTER 1

## 1.1 INTRODUCTION

There has been a growing concern over the increasing need for transport in urban environments. The concern is basically of the need for an efficient system of urban mobility that will enhance smooth interaction between the various landuse zones in cities.

During the period of early urban settlements when transportation was by traditional methods, streets were designed to meet the specific traffic needs of the time. However, as cities grew in terms of population and size, more streets were required to cope with increasing demand. Consequently, the problem of how to move efficiently within the urban environment became paramount in the minds of the people.

Since the emergence of the horse car, in the early $17^{th}$ century in Europe and America, urban areas have witnessed the introduction of several technological inventions in transportation aimed at enhancing mobility. The street networks are redesigned (in various designs) and off-street traffic facilities are installed. In the last three decades, the rate of urbanization particularly in the cities of the Less Developed Countries, have made the structure of cities very complex and diversified in the functions they perform. Hence, the landuse pattern of an area is highly related to the transportation system. It is often stated that the changing pattern of landuse and urban development have a direct impact on the pattern of transportation in the city (Webster and Bly, 1987).

When urban environments undergo rapid changes, more transport facilities are required to move efficiently. In Nigeria for example, the land use pattern has become diversified into functional groupings of residential, commercial, industrial, educational activity etc, thereby necessitating an increase in the demand for transportation in the cities. In some urban centres of Nigeria, the intermingling of landuse, the poor level of planning and the human misuse of the roads combine together to inhibit the smooth flows of traffic (Mala, 1999).

In Calabar, during the early $20^{th}$ century, when it was the headquarter of the Eastern division, with a cosmopolitan character and polygot population, the physical planning of the town was purely on an ad-hoc basis as the native towns sprawled towards each other, whereas the roads and tracks crossed and re-crossed without any system. Today, Calabar does not retain the same set of characteristics it possessed in the $20^{th}$ century, especially as it has crossed a critical threshold into what is generally termed the 'process of development.' It is evident that in an effort to redress the problems of the feeble and poorly connected road network, several road improvement measures have been adopted.

In order to evaluate the problems associated with poor road networks and adequately assess road development in cities, an efficient data acquisition technique – such as provided by remote sensing – is required.

Remote sensing as we may simply know is the examination of, the obtaining of information about an object or phenomenon at distance from it, without physical contact with it. So far, the use of photographic sensor systems – which produce imagery when reflected energy impinges directly on a photographic emulsion – in black – and – white, color and false color have been widely applied. Infact in no field has aerial photography been so long utilized, and successfully too as in the field of transportation studies. Since the 1940s the use of medium-scale aerial photographs to map landuse and research into transportation has been proceeding. A survey of major U.S high way organizations in the 1980s revealed that 62 to 75% of the organizations utilized aerial photography in highway planning.

So, in this study, an attempt is made to identify the urban roads, and analyse their efficiency in catering for urban mobility. This is basically focused on finding out the attention been paid to feeder roads and the provision of road traffic facilities.

## 1.2 PROBLEM STATEMENT

The development of roads is a major feature in expanding urban centres. Roads are meant to ease mobility, and are created generally speaking where the need for movement is concentrated.

From previous studies it has been established that remote sensing provides a means for discerning physical growth and development within an urban area.

Since the commencement of structural development – road construction particularly – in Calabar; from the early days where there were motorized carts for passenger transportation, there ought to be a periodic assessment of the rate of development and adequacy of roads to increasing demand through a viable data based technology.

A detailed examination of the urban development and urban transport facilities in some urban centres reveals that these towns have been growing rapidly without a corresponding provision made for adequate road space and other urban transport infrastructure (Adeniji, 1981).

In the urban centres, existing road networks form a confusing pattern; there is irregularity in the shape and size of roads serving the same functions. These variations create bottlenecks to free flows of vehicular transport.

In an effort to accommodate the increasing demand for road space and ease the bottlenecks, several road development works have been undertaken. But what remains puzzling is that these has not paid an adequate attention to the feeder roads and the provision of road traffic ancillary facilities that are largely crucial to the efficient flow of traffic.

## 1.3 OBJECTIVES OF STUDY

This research work seeks to achieve the following objectives:

1. To map and describe the existing road network
2. To assess and determine the rate of road development in the study area
3. To enable us determine the available road traffic ancillary facilities and
4. To determine the road plan efficiency

## 1.4 JUSTIFICATION

The character of land use defines the location of people and activities, thereby necessitating the demand for movement. This according to Asuquo (1981), affects the ease of travel between locations and hence, in some situations, even determine the value and use of land. However the desire to foster the social and economic growth of cities through interaction , especially in the developing countries like, Nigeria, is constrained by a number of reasons among which include the dearth of planning data and knowledge.

Hence, this study is necessary as it enables the determination of the rate of road development; hence projections can be made on what is to be done to meet up with prevailing needs. Also this will provide the city planning authorities with transport data to properly integrate into the land use planning process.

## 1.5 SCOPE

This study is focused on capital city of Cross River State – Calabar, with a case study of Calabar municipality. It is worthy to note that the Calabar municipal area presently consists of ten wards , but this study is limited to eight wards due to the fact that, data on these wards abound and roads are concentrated there.

The developmental parameter to be measured and assessed in this study shall be restricted to roads in terms of length and width for obvious reasons

## 1.6 STUDY AREA

Calabar Municipal Council Area, otherwise known as Calabar – North Local Government Area; carved out from old Calabar Capital city area in 1996 is today established as a political, administrative, cultural, social and business centre as well as a port town.

It is located between longitudes $8^0$ 18'E and $8^0$ 25' E and latitudes $4^0$ 56 'N and $5^0$ 06 'N

As a result of urban growth and expansion coupled with the creation of Calabar – North Local Government Area, there is a gradual growth of multiple business nodes, such as around Ika-Ika-Oqua market, by Ndidem Usang Iso way, around the intersection of Atekong drive and Ndidem Usang Iso way, around Effio-Ette junction (MCC road by Ndidem Usang Iso Way) and Old Odukpani Road, by Murtala Mohammed Highway. Following this general dispersion of economic activities is a greater demand for transportation. as more commodities and persons require movement into and out of these areas.

In Calabar Municipality, roads and streets lack regularity both in terms of direction and width as can be respectfully seen in the winding Ediba Road and Old Odukpani Road, and the section of Akim Road linking Eta Agbo Road to Ndidem Usang Iso way. Also, the houses are irregularly positioned, and this is dominant in the highly populated substandard residences prevalent in Edim Otop, Big Qua Town and Akim Qua Town. This is basically an extension of village attitudes to city development than a product of the dictates of the terrain. These irregularities in street order and housing layout have impeded proper access road development and route connectivity, resulting in tedious personal and freight transportation.

### 1.6.1 **GEOLOGICAL FORMATION.**

The area of Calabar (including unexposed rocks below superficial soil and vegetation cover) is covered by younger granitic, volcanic and sedimentary rocks which range in age from about the Jurassic period (i.e. about 190 million years ago).

In the valleys of the Cross River and in the coastal margins of the area. cretaceous rocks are found, whereas sedimentary rocks which bear limestone deposits are found on the northern margins.

### 1.6.2 DRAINAGE PATTERN

Calabar Municipal area is drained by two major rivers; the Cross River to the left and the Great Kwa River to the right.

The Cross River which is more significant, rises in the mountains of Southern Cameroon and flows in a great arc northward round the Oban hills before reaching its estuary. It has a total length of about 483 Kilometres, The lower stretches of the river are bordered by mangrove swamps, but the upper reaches flow through high forest; which includes mahogany and the ubiquitous oil palm.

### 1.6.3 CLIMATE

Calabar lies in the humid equatorial belt, often greatly influenced by oceanic currents. The local climate of the city is often different from the suburbs. Perhaps the most obvious difference is in temperature, particularly at night. During the day the concrete and tarmac of the city absorbs more of the sun's heat than surrounding vegetated surfaces. At night this heat is released, making the air warmer, especially when there is no wind to keep the warm air from moving away from the city.

Generally, temperature is highest from February to April, and lowest in July and August; with slight seasonal change of maximum temperature. The minimum temperature is about $22^0$c, whereas the maximum temperature is about $30^0$c.

This area is characteristically a rainfall belt, with monthly averages always about 200cm. However, the rainfall season stretches from April through November. The rainfall intensify evidently decreases fairly sharply, inland.

## 1.6.4 **LAND USE PATTERN.**

It should firstly be noted that, land is not homogenous and that it is not accessible and utilizable for all the basic needs.

In Calabar Municipality, the character of land use defines the location of people and activities, thereby necessitating the demand for movement. Areas connected to a network of routes command higher land values than places with lower transport connections. The C.B.D. is such a good interface of land use growth/transportation relationship.

The city's financial institutions and government offices are basically located in the South-West corner, extending along Calabar Road through the lower reaches of Diamond Town to its adjacent area bounded by Murtala Mohammed Highway. Whereas, residential locations are quite irregularly distributed over the townscape with the dominant highly populated sub-standard residences occuring in Edim Otop, Big Qua Town and Akim Qua Town. The better planned state and Federal Housing high-class building residences with lower population densities are located in Ediba and Ikot Ansa respectively. In addition, low density residential suburbs with semblance of satellite settlements, exist in the Esuk Utan industrial area.

Economic activities in Calabar which are dominantly non-basic comprising of convenience goods and services that are in everyday use are scattered more or less according to population distributions over a poorly connected route network.

Agricultural activities are chiefly low-scaled in the city area, as home farms and gardens are dominant, whereas plantations and bush farms are found in the suburban areas of Ikot Ansa, and Ikot Effanga. Due to agricultural development, settlement, industrial establishment, road building and other social infrastructural development, the high forest has been grossly reduced if not erased in this area. However, traces could be seen along the banks of the Great Kwa River and in Ikot Omin.

The City's major industrial area exists within Esuk Utan and Ekorinim, where the Export processing zone and Nigeria Ports Authority are located.

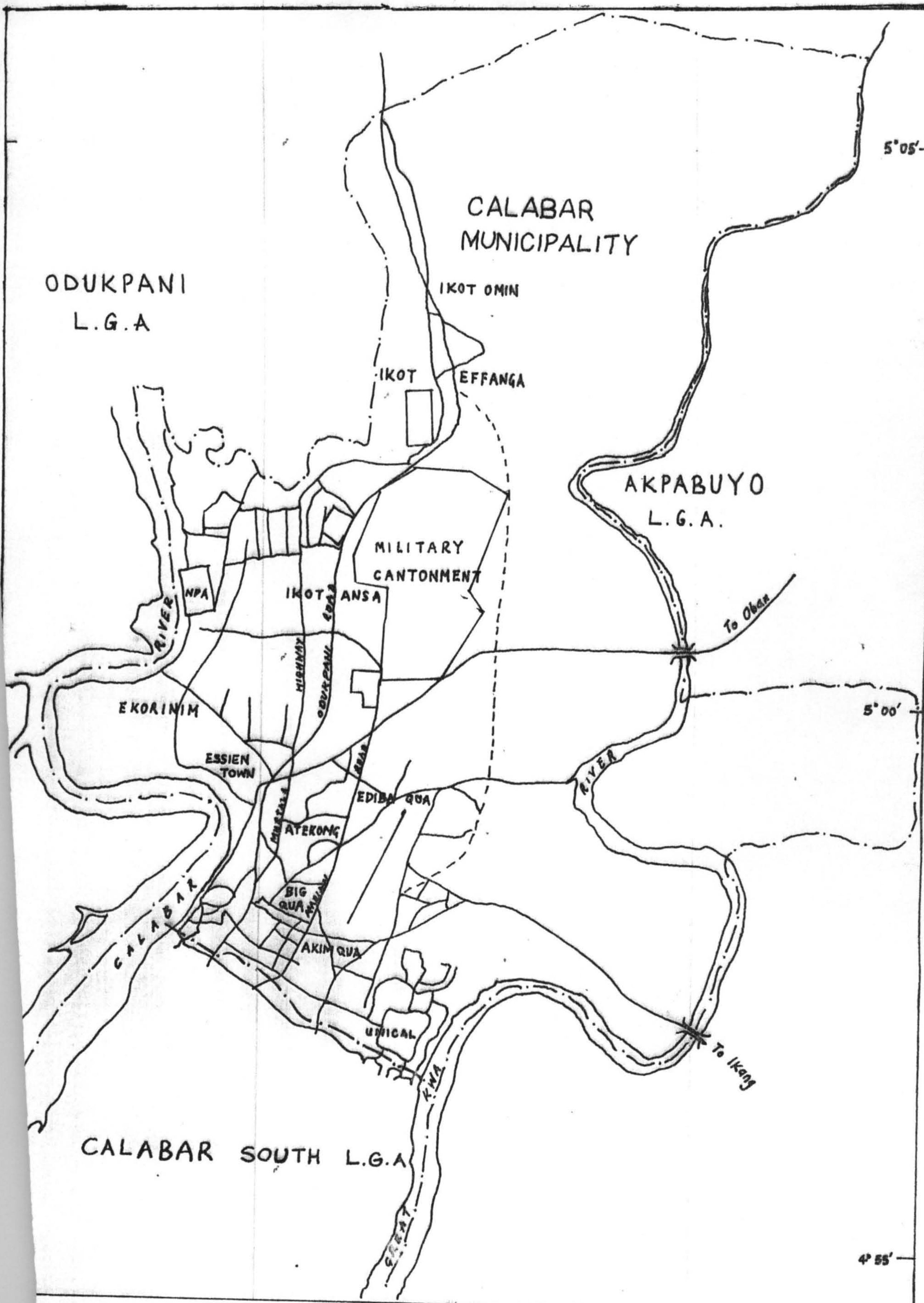
### 1.6.5 **POPULATION**

The population of Calabar has been rising steadily over the years, especially after 1967 when Calabar became the capital of Cross River State. Also, due to the end of the civil war as rural migration to Calabar became prominent (Obot 1980, p.4.4).

In 1953, the population of Calabar stood at about 141,000; this rose to about 267,014 by the year 1963. Even with the creation of Calabar Municipal Government Area out of the old Calabar, the Calabar Municipality has an estimated population of about 200,000 by 1997 (Economic Planning Department, 1997).

Today, with an estimated population of about 235,000, spreading over an area of approximately 248.7 square kilometers; the population density is low to medium for an urban area.

# IG 1.1: CALABAR MUNICIPALITY AND ENVIRONS




SCALE 1:100,000

LEGEND

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

A review of various literatures from past researches point to the fact that, urban land development (or change) surveys can be conducted through remote sensing techniques. Furthermore, with the use of multi-temporal photograhic data, changes in the townscape can be discerned and monitored: given cloud-free conditions.

This can be explained as below in the sections provided:

### 2.1 DEVELOPMENT OF AERIAL PHOTOGRAPHS

The effective development of Aerial photography and photographic interpretation dates back only to the later part of the nineteenth and the early part of the twentieth centuries (ASP, 1975). Although, the basic principles and techniques have been earlier formulated since the mid-eighteenth century when J.H. Lambert published his findings on the theory of perspective drawing for determining dimensions. Lamberts' idea forms the basis of modern photogrammetry (ASP, 1975)

Photography itself was invented in the 1830s in France by a Scientist called Louis Daquerre, who worked in association with another French Scientist, Nice-Phore Niepce (ASP, 1975). Its subsequent development was prompted by the need for the French Corps of Engineers and the Paris observatory to produce detailed and accurate topographic map; which subsequently lead to the development of aerial photography. It was indeed, a member of the corps of engineers, Colonel Aim Lausedat, who worked out a procedure for making measurements and compiling maps from aerial photographs (ASP, 1975).

The first aerial photographs were taken over Paris on 1858 from a captive Ballon (ASP, 1975). The photographer, Gaspard Felix Tournachon, had used the ordinary hand camera, but soon aerial camera which automatically took photographs of the earth's surface at regular intervals were designed to be carried aloft baloons and kites (ASP, 1975).

The first aerial photographs taken from an airplane were those of Centocelli. Italy, in 1909 and the First World War. which began a few years later gave a great impetus to the development of aerial photographic interpretation, particularly for military purposes (Areola, 1986). Indeed. aerial photographic reconnaissance of war fronts and enemy territories soon came to be regarded as being of the utmost importance in the planning of both military offensives and counter-offensives in safeguarding vital supply routes; and in making models of the terrain in order to plan troop movements and manoeuvers (Areola, 1986)

Up to the end of the Second World War, aerial photographic interpretation was mainly developed for military intelligence (Areola, 1986). Nevertheless, significant progress had been made in the scientific and practical uses of aerial photography and this was particularly of the U.S.A where extensive use of aerial photography was made by such agencies as the soil conservation service, the forest service, the Geological Survey. the Tennessee Valley Authority and some Urban/Town Planning Authorities (ASP, 1975).

Also, the British initiated exploratory projects in several parts of the empire aimed at assessing the potentialities of Aerial photography for various purposes (ASP, 1975). In Britain, Canada, Australia, Tasmania and the Middle East for instance, aerial photographs were used for geological, archeological, ecological and urban studies etc. (ASP, 1975).

The post war reconstruction after the Second World War and other developmental processes like Industrial, Transport, Mineral Exploration, Urban renewal and planning etc, used greatly the aerial photographs and ground photographic surveys to provide data and working documents for planning purposes (Areola, 1986).

The sequential development of Aerial photographs led to the preparation of Mosaics and subsequently ortho-photomosaics. The ortho-photomosaic is an assembly of ortho-photographs cut to make inconspicuous joint and make to fit control points exactly. (Wolf. 1983).

The 1960s and 1970s were formative years in which usual interpretation of black and white aerial photographs parallel research into the use of data from the new aircraft and satellite –borne sensors. (Curran, 1985).

## 2.2 REVIEW OF URBAN DEVELOPMENT STUDIES BY AERIAL PHOTOGRAPHY.

The aerial photographic technique of remote sensing has proved extremely effective as a reconnaissance tool in permitting the survey of remote and inaccessible areas which have otherwise not been assessed for a long time.

In series of township photographs produced over the years, it has proved useful in studying land use, residential patterns and the spatial growth of urban centres (Areola, 1986).

Aerial photography is used in urban studies not merely to present static pictures of urban land use but perhaps, more importantly, to assess, analyze and map the temporal changes in land use and spatial growth of a city (Areola, 1986). The major singular reason for the services of urban photography that has been provided for many urban centres is to assess the spatial changes (Areola, 1986). According to Areola (1986). "it is unfortunate that not much materials has been published on this type of application of aerial photography in Africa".

Adeniyi (1978), studied the land use changes of Lagos, Oyelese (1968), analyzed and mapped the land use pattern of Ibadan city using the 1:40,000 photographs taken in 1965 and Grenzebach (1978) has equally used sequential aerial photographs to describe stages in the growth of metropolitan Lagos.

Urban growth detection using aerial photography has been applied in several areas and found to be an efficient method of discovering the development trend of a region (Lo, 1986). Growth detection obviously involves the use of sequential aerial photography over a specific region. (Lo, 1986).

An urban change or growth map between two or more time periods is usually produced to evaluate the rate of urban land use changes and possible economic benefit associated ( Campbell 1983).

It is often stated that the changing pattern of land use and urban development have a direct impact on the pattern of transportation in the city (Webster and Bly, 1987).

Although since the 1940s, the use of aerial photographs to applications in urban studies have been carried out by earlier mentioned authors, this is evidenced also by the works of Branch (1948), Witenstein (1952, 1954, 1956), Avery (1965), Board (1965) among others; it has been gathered that in no field has aerial photography been so long utilized and successfully too, as in the field of transportation studies.

Aerial photography has been of great assistance in various location and siting problems, such as transport route location among others. First, the factors to be assessed in the route selection process are determined. Natural and cultural features plus various economic, social and political factors are considered. Then, data files containing information on these factors are assembled and alternative routes are then analyzed, and the final route is selected. The task of analyzing natural and cultural data is facilitated by the use of land information system.

In the application of aerial photography to land use change studies, need be to mention the work of Eastman 1988a and 1988b; where he undertook land use change detection from sequential aerial photographs.

Focusing attention on the detection of land use change, Avery (1965) used aerial photographs taken between 1944 and 1960 at a scale of 1:20,000 to evaluate land use and land cover changes in Dark country of Georgia, USA. He advocated for the development of a spatial system solely for the purpose of detection and recording of land use changes, so that maps and data banks can quickly be updated.

Simpson et al (1970), in their study of Boston used aerial photographs at a scale of 1: 120,000 with the purpose of preparing land use maps and a computerized data for the metropolitan region. The land use map was compiled directly from the photographs (on overlays).

Lo and Shipman (1990), carried out a study on Geographic Information System (GIS) approach to land use change dynamics detection. This was applied to assess the impact of New Town Development in Tuen Mun, New territories, Hong Kong, on the environment through integrating of past and current aerial photographs which were taken in 1976 and 1987 at a scale of 1:25,000 and 1:40,000 respectively. Image overlaying and binary masking techniques are used. The result showed that the binary masking method reveals the dynamics of land use change.

Adeniyi (1980), employed the use of sequential aerial photographs of Lagos state and computer assisted mapping. The aerial photographs utilized were of 1962 and 1974 at a scale of 1:40,000 and 1:20,000 respectively. A minimum mapping unit of one hectare was used as basis for interpretation and for subsequent storage of land use data into the computer. The data bank created from the study was helpful in updating of data and integrating with other types of data for urban research and planning.

Khoria (1993), using sequential aerial photographs studied the vegetation and land use changes in the rain forest region of North-East Edo State. The result showed a great reduction of forest lands and woody shrub grassland between 1967 and 1977, and notable changes were recorded in settlement areas.

Aerial photography has thus shown its ability to successfully provide urban environmental data sought after, for various applications. A survey of major USA highway organizations in the 1980s revealed that 65% to 75% of the organizations pooled, utilized aerial photography in highway planning. This was possible through the provision of qualitative and quantitative data about:-

i ground surface required for route location,

ii preliminary survey and design,

iii location survey and

iv construction stages of urban highway projects.

Despite the enormous potential of the conventional aerial photography in providing a detailed inventory of the earth's surface, its resources and their use, there are limits to this process, and difficulties in practical use. Some of these, such as the fragmental format of air photos, are not really serious; others, as with the limitations of the human eye in differentiating photographic detail, are quite fundamental. Although there have been attempts to overcome these limitations, the developments are quite less easily accessible for applications. Notwithstanding this situation, this study will through an efficient methodology contribute to the effectiveness of aerial photographic remote sensing in study of urban road development in Nigeria.

# CHAPTER 3

## 3.0 METHODOLOGY

The method of study for this research is by remote sensing techniques (using aerial photographs), complemented with topographic maps, photomaps, ground truth data/field surveys and library information.

The following methods have been employed in generating and analyzing the data used in this research.

### 3.1 METHOD OF DATA COLLECTION

Since the method of study for this research is diverse, the methods of data collection is informed by the data required for the study.

#### 3.1.1 DATA REQUIRED

For this research, primary data, basically derived through first-hand surveys and field work are required. Also, secondary information with direct and indirect reference to this research are required.

#### i AERIAL PHOTOGRAPHS:-

The aerial photographs acquired are in two folds, viz: Aerial photographs and photomaps:-

a Aerial photographs and photomaps covering Calabar Municipality for – March 1972 at a scale of 1:40,000 and 1:30,000 respectively.

b Aerial photographs and photomaps covering Calabar Municipality for April 1991, at a scale of 1:33,000 and 1:30,000 respectively.

These data set, provides a good ground observation, broad spectral sensitivity and a three-dimensional view. Equally, these are the data that were readily available.

Full technical details of these aerial photographs are shown in Table 3.1. A total of four photographs was employed for this research – two for 1972 and two for 1991 (Figures 3.1 and 3.2)

TABLE **3.1: CALABAR MUNICIPALITY PHOTOGRAPHIC INFORMATION**

| | 1972 Photographs | 1991 Photographs |
|---|---|---|
| Date of acquisition | 19th March 1972 | 7TH April, 1991 |
| Scale | 1:40,000 | 1:33,000 |
| Focal Length | 88.97mm | 88.707mm |
| Flying height | 3,904m | 2,744m |
| Film format | 23 x 23cm | 23 x 23 cm |

See Figures 3.1 and 3.2 on Pages 20 and 21.

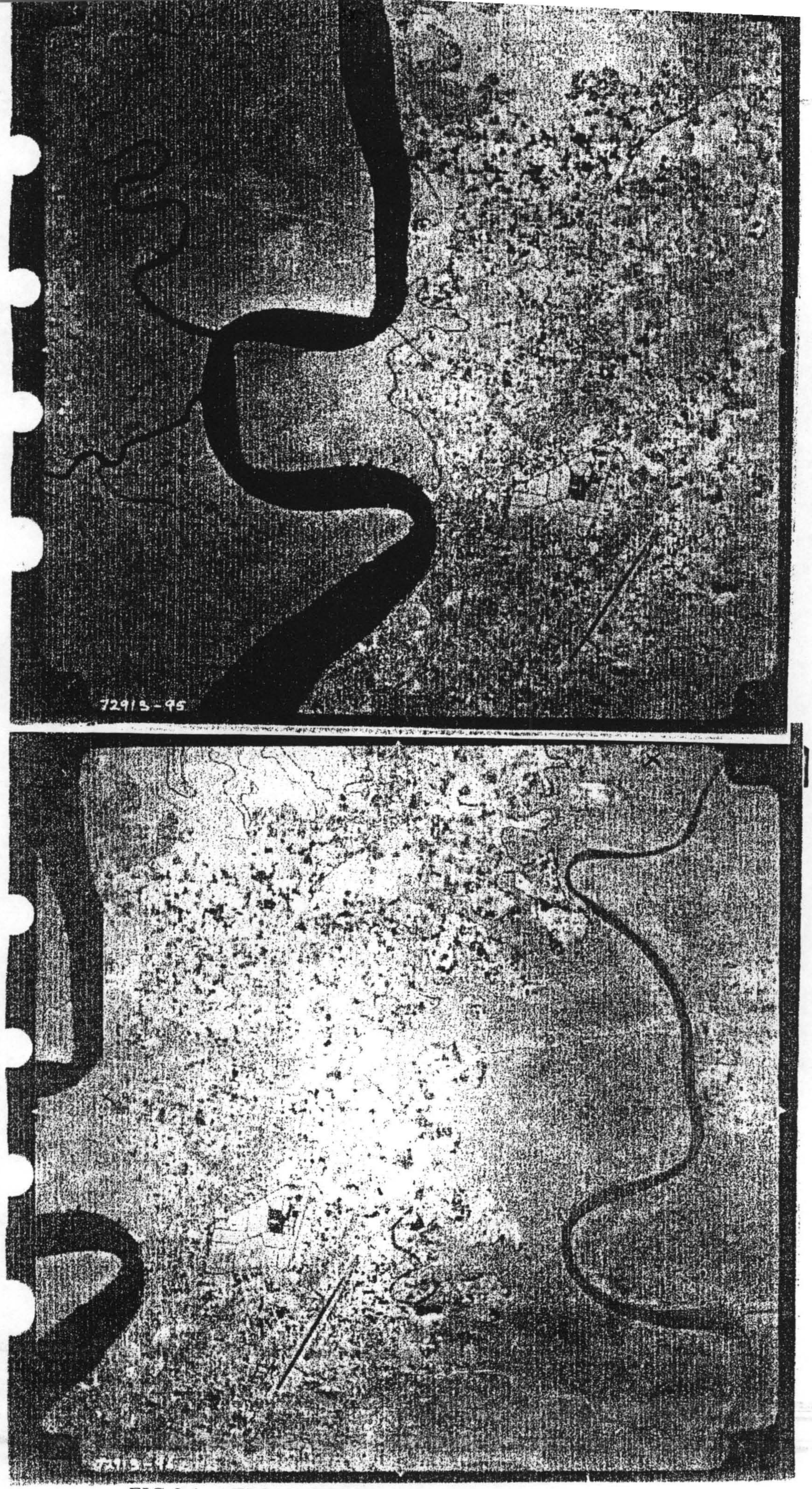



FIG 3.1: AERIAL PHOTOGRAPHS OF Calabar, 1972.

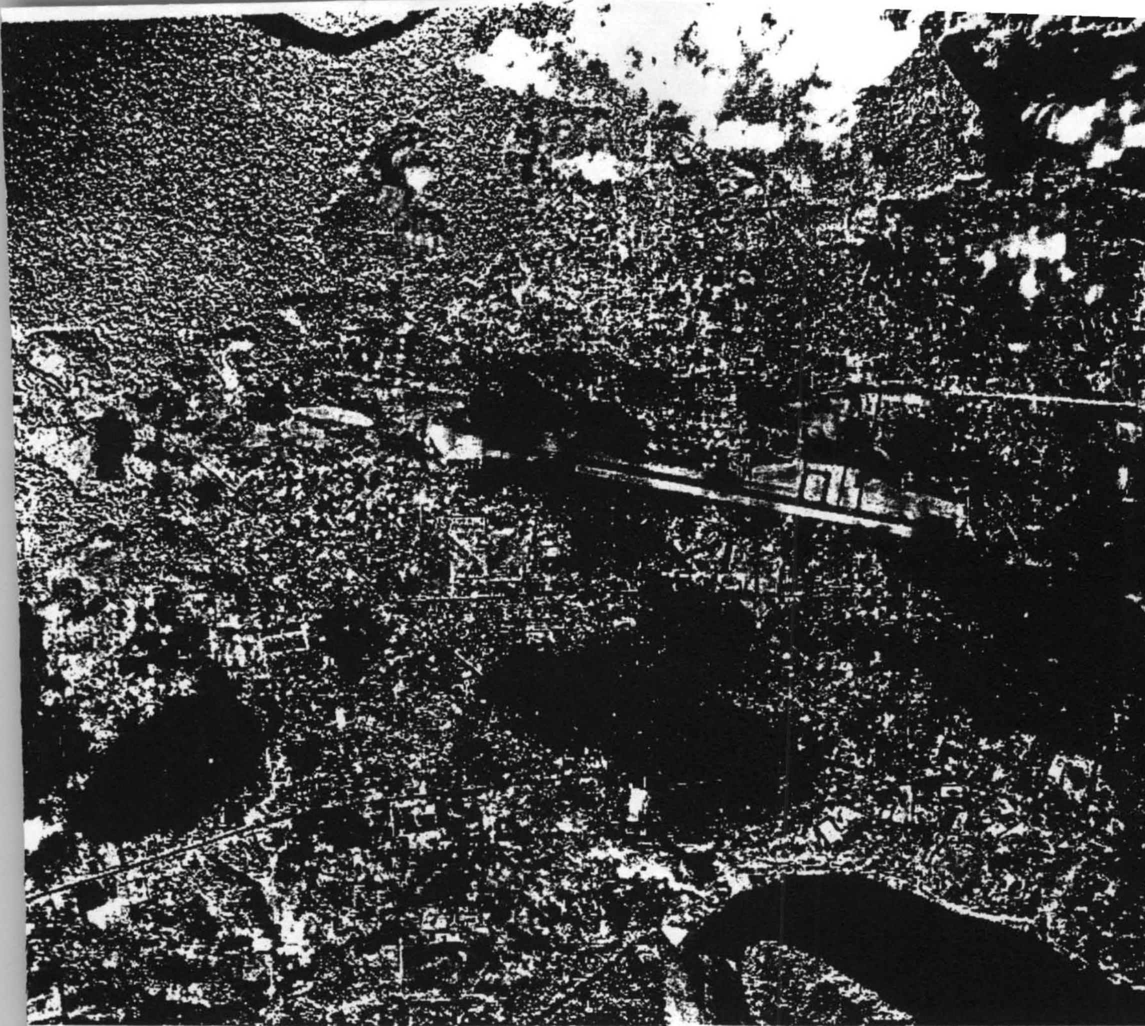




FIG 3.2: AERIAL PHOTOGRAPHS OF CALABAR, 1991.

ii **CARTOGRAPHIC DATA:** complimenting these photos are guide map of Calabar for 1972 at a scale of 1:15,000 prepared by the Cross River State. survey, Calabar; Calabar Masterplan, prepared by Town Planning Division, Calabar and the Calabar Survey map at a scale of 1:30,000 prepared by the Survey Department, Ministry of Lands and Survey, Calabar.

iii **GROUND TRUTH (FIELD DATA).** In remote sensing, rarely is any study done without the use of some form of reference data.

These set of data are necessary to gain a first hand knowledge of the details of the study area street width and condition, curb and sidewalk presence and condition, availability of parking facilities, activities on the landscape and the urban spatial structure in relation to the data obtained from the aerial photographs and maps. The acquisition of reference data, hence involves collecting measurements or observations about the objects, areas, or phenomena that are being sensed remotely. These data can take on any of a number of different forms and may be derived from a number of sources. For example, the data needed for this particular study may stem from a "field check" on the identity, extent, and condition of Urban roads, traffic facilities and other terrain features.

Also, personal interview session data with officials of relevant Ministries and authorities were recorded.

The information obtained here was quite useful in minimizing the effort in taking a sample of the whole area, and hence in undertaking the study.

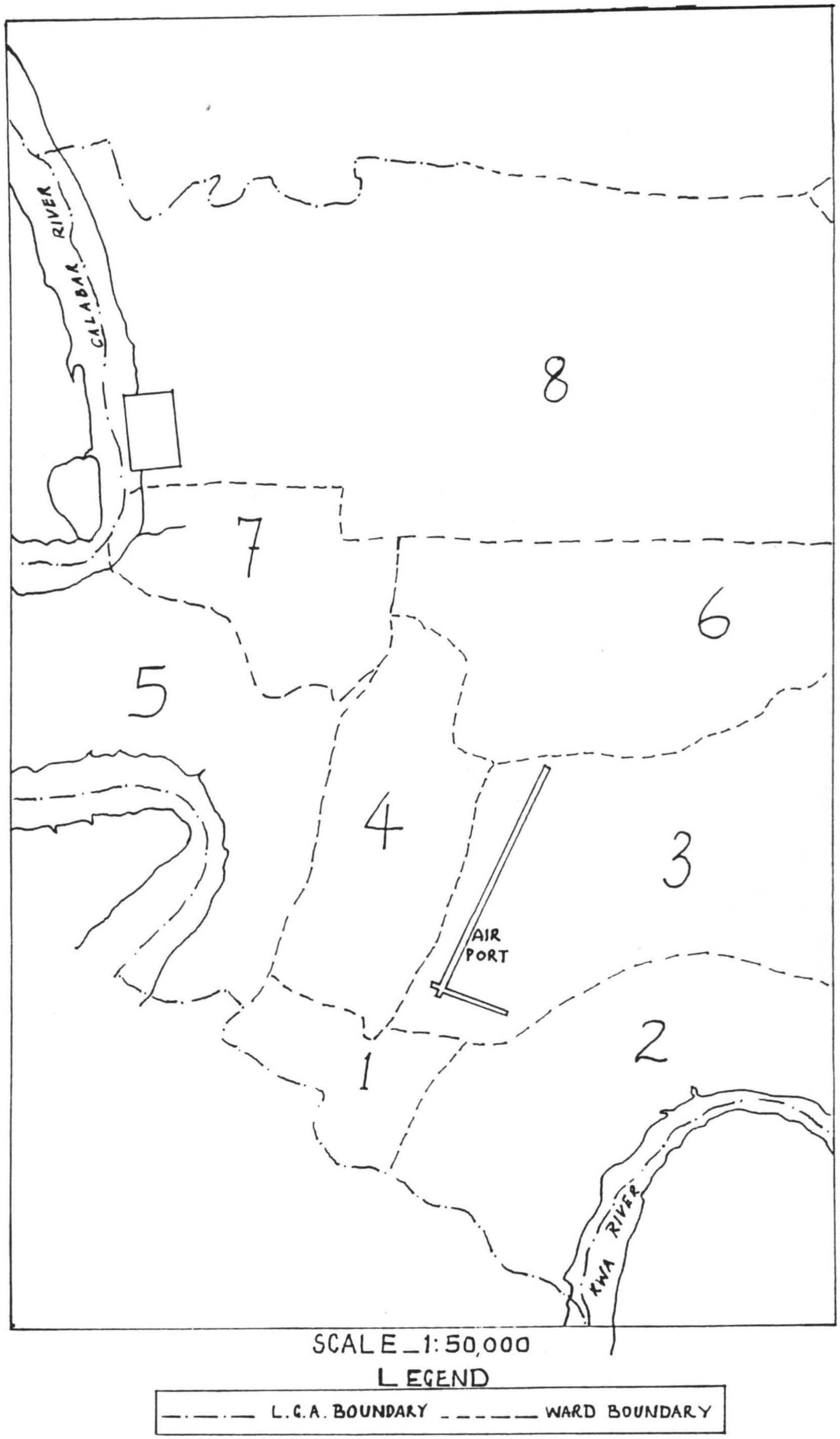
iv **LIBRARY DATA:-** These include both published and unpublished literature on network pattern, urban transport, urban change detection, mapping from aerial photographs, and a range of other materials related to network analysis and applied remote sensing. These materials which acted as supplement to the primary data were obtained by searching and surveying textbooks, journals, articles, government gazettes and on maps found relevant to this study.

### 3.1.2 SAMPLING PROCEDURE

Due to the limited time and resources available to undertake this study, a sample of the entire urban roads in Calabar Municipality was studied under a natural setting. Equally, since Calabar Municipality consists of ten wards with only eight wards bearing 'truly urban' characteristics and a concentration of roads; the areas of Ikot Mbo Rubber Plantation (North-West of Federal Housing Estate), Ikot Effanga and Ikot Omin (North of Ward eight), East of Eastern Highway (proposed) and the western region of Ekornim which lack these characteristics were excluded. In addition, for this peculiar case study which is focused on networks and the need for contiguity, a generous sample size of roads was systematically chosen for proper coverage of the study area.

The boundary of the study area (the eight wards) was clearly defined by overlaying a transparent sheet on the map.

Fig.3.3: **DELIMITATION OF STUDY AREA: THE EIGHT WARDS**



Afterwards, the land area of the various wards was computed using a planimeter; and the area values of the wards are shown in the next chapter as Table 4.1.

Then, all the 'surfaced' roads in the eight wards (study area) were serially numbered and their lengths measured; as shown in Appendix A (length of roads in Calabar Municipality; 1972 and 1991).

From the entire population of forty roads, the following numbers were systematically chosen to establish the required sample of twenty roads:

1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, and 39.

## 3.2 METHOD OF DATA ANALYSIS

Considering the research objectives and sampling method, it is required that the assessment of urban road development in Calabar Municipality be objectively presented. So, in order to analyse the data for objective assessment, the following data analysis techniques were employed:-

3.2.1 **VISUAL IMAGE PROCESSING AND ANALYSIS:-** This method involves the visual interpretation of various multidate aerial photographs, after which the changes and development in the roads were mapped accordingly. However, some preliminary routines of photo and image interpretation were properly taken into cognizanc;. there include:

a. procure the appropriate photographs for the purpose

b. examine the photographs to ensure that they are suitable for the purpose; that they cover the desired area and that they are no gaps or misaligned strips.

c. prepare the photographs for interpretation:

i. prepare a photomosaic

ii. Mark principal points, wing points, tie points, and control points

iii. Transfer the points

iv. Place overlay on photographs

v. Mark the principal points, wing points, tie points and control points on the overlay.

d. **Interprete the photographs:-** This involves observation, detection, recognition or identification of features; classification and deduction. There are three major processes involved in the interpretation:-

i. **Image reading:-** The simple identification of objects using elements such as shape, size, pattern, tone, texture, color, shadow, site and association.

ii. **Image measurement:-** The extraction of physical quantities such as length, location and density of roads etc by using reference data and mapping the area of study by transparent overlay, deductively.

iii. **Image analysis:-** The understanding of the relationship between the interpreted information and actual status of the phenomenon; which enhances further evaluation of the urban road development information.

**INSTRUMENTS/MATERIALS USED FOR THE VISUAL ANALYISIS:** The major instruments and materials used in the image data processing and analysis includes:-

(i. Mirror and pocket stereoscopes

(ii. Magnifying lens

(iii. Planimeter

In order to apply such mathematical techniques, the network is considered to be a graph – like structure, made up of its points [referred to as nodes (n)],actual links [referred to as edges (e)] and also, possibly some sub-graphs (p). Two different kinds of network known as planar and non-planar graphs, can be identified according to the nature of their structure. Planar graphs being those in which the edges have no intersections except at the nodes.

Two of the main characteristics which can then be measured are the extent and the connectivity of the network. The extent of the graph (also regarded as the degree of the development of networks) can be effectively measured by the pie (Π) index; which compares the total length of the network (c) with the network's diameter (d).

$$\Pi = \frac{c}{d}$$

Where c = total length of network; and

d = maximum number of edges in the shortest path between each pair of nodes.

The greater the value of pie, the greater is the extent of the network. Kansky (1963), has shown that, in general, network structures in developed countries have a greater extent (higher pie index) than networks in relatively underdeveloped countries.

The connectivity of the graph can be measured by several different indices, of which the most useful is probably the Alpha index; developed by Garrison and Marble (1961), which consist of the ratio between the observed number of fundamental circuits and the maximum number that may theoretically exist in the network. The observed number of circuits is given by the formula:

$$\mu = (e - n) + p$$

Where $\mu$ is called the cyclomatic number.

The maximum theoretical number of circuits is given by the formula:

$2n - 5$, for planar graphs and by:

$$\frac{n(n-1)}{2-(n-1)} \text{ for non-planar graphs}$$

hence, for a planar graph, the alpha index is calculated using the formula:

$$\frac{(e - n) + 1,}{2n - 5}$$

where $(e - n) + 1$, is the cyclomatic number,

$2n - 5$ is the maximum possible value of a cyclomatic number.

The values of the alpha index will occur in the range, zero to one or zero to 100 for percentage values, with 'zero' indicating a simple network. Once again, Kansky was able to show that there was a correlation between level of development and the degree of connectivity of a nation's transport network.

More refined techniques which gave more efficient description of network structure (such as the Shimbel index) have been obtained by treating the network as a connectivity matrix (Pitts, 1965) and by the use of principal components or factor analysis (Goddard, 1968).

The Shimbel index is a standard technique used for measuring the accessibility of one node to all other nodes, and so can be used to show the possible number of edges that are required to connect any node with all other nodes on the network by the shortest route.

By treating the network as a connecting matrix, it shows the number of edges separating various nodes. This is computed by counting the number of actual edges between nodes on both rows and columns of the matrix.

The total accessibility of an area is determined by the Dispersion index; which is the summation of the total linkages between all the nodes; obtained by adding all the Shimbel indices together.

The mean Shimbel index, which is the mean number of edges required to connect any node with all the other nodes on the network is obtained by dividing the total accessibility of the network by the number of nodes or vertices.

$$\text{Mean Shimbel index} = \frac{\text{Total accessibility}}{\text{Number of nodes}}$$

The higher the accessibility (Shimbel) index for an area, the lower is the degree of accessibility predicted for such an area, and the lower the accessibility (Shimbel) index for an area, the higher is the accessibility predicted for that area (Tidswell, 1988).

The beta index is another efficient measure of network connectivity; as it makes useful quantified comparisons of network connectivity. It is arrived at by dividing the number of edges (e), in the network by the number of nodes (n) in the network. This is given by the formula.

$$\beta = \frac{e}{n}$$

where $\beta$ is beta index

e is total number of edges

n is total number of nodes

values for the beta index range between extremes of zero and three. Where the value is less than one, the network has poor (disconnected) links, where it is one, the network has a single circuit (without branches), and it is more than one, where the network is complex and contains more than one circuit.

Then, the rate of road development in the study area will be obtained using the formula:

$$\frac{B - A}{A} \times 100$$

Where A, is total length of roads in the reference year, and

B is total length of roads in the terminal year.

The values which will be in percentage, provides a measure for obtaining the average yearly value of road development.

In addition, the road network density of the study area will be obtained to show the relationship between a unit area and the length of roads in the study area. This is simply computed by dividing the total length of a network by the area it covers.

It can be given by the formula:

$$D = \frac{L}{A}$$

Where D is density of network

L is total length of network, and

A is the area it covers.

On the whole, all of these techniques will be applied accordingly to adequately and objectively describe and analyse the road network structure of Calabar Municipality.

# CHAPTER 4

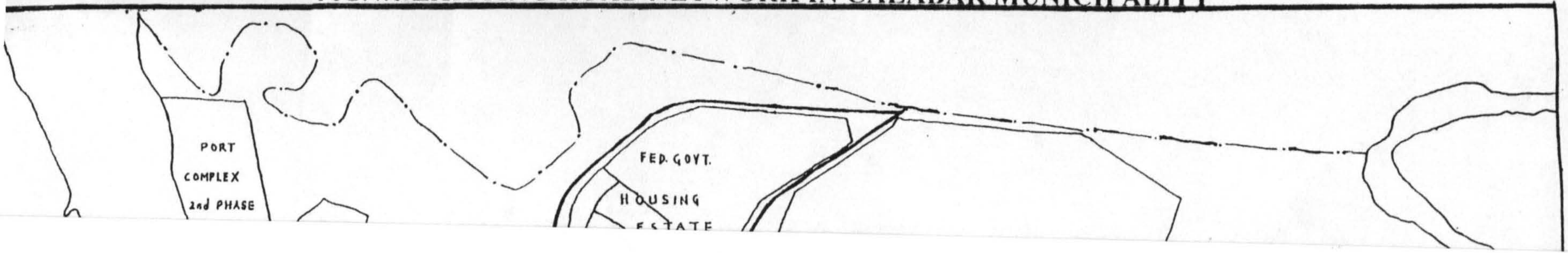
# 4.0 DATA PRESENTATION, AND DISCUSSION OF ANALYSIS

## 4.1 STRUCTURE OF ROAD NETWORK

The description and analysis of the structure of road network would be undertaken through the use of the alpha index, beta index, and Shimbel index, supplemented with a road network map.

Roads in Calabar Municipality are diverse in shape and size, ranging from a few single roads to an irregular network of major roads, feeder roads and junctions which reflects the trend of city expansion rather than a product of the dictates of the terrain. While there is a concentration of winding roads with inadequate space in Akim Qua, and Big Qua towns, there are regular roads with adequate space around and within the better planned State and Federal Housing Estates. Whereas, quite a few criss– cross the terrain, for example the Quarry Road, Ediba Road and old Odukpani Road.

FIG.4.1: **EXISTING ROAD NETWORK IN CALABAR MUNICIPALITY**



From the route map, it is difficult to describe the road network structure based on visual impressions of the lines as they cross each other at nodes (junctions), due to its less obvious form. Although it can probably be judged that the Akim Qua and Big Qua Town areas have a more complex structure of road network than the Ekormim and Ikot Ansa areas, due to the visual differences in route density and layout. This description based on visual impressions is subjective and inaccurate.

Due to the subjectivity and inaccuracy of the description based on visual impressions, the graph theory is used.

### 4.1.1 ALPHA INDEX OF CALABAR MUNICIPALITY

The alpha index as earlier stated is a quantitative measure of network structure, and it indicates a departure from simpleness in the direction of complexity. Hence, it provides a very useful descriptive measure of linear structures.

Though it is quite advantageous, there is a likely weakness. In many cases where the delimitation of study area is applied, it is quite arbitrary and the sample size chosen, affects the index derived. So, for this study, the area chosen for calculation is reasonable in relation to the investigation, as stated in section 3.1.2.

TABLE 4.1: **AREA OF WARDS IN CALABAR MUNICIPALITY**

| NAME OF WARD | AREA $(KM)^2$ |
|---|---|
| WARD 1 | 2.52 |
| WARD 2 | 9.27 |
| WARD 3 | 28.53 |
| WARD 4 | 5.49 |
| WARD 5 | 9.36 |
| WARD 6 | 9.45 |
| WARD 7 | 3.78 |
| WARD 8 | 26.37 |
| TOTAL | 94.77 |

**Source:** Photomaps of Calabar; 1972 and 1991

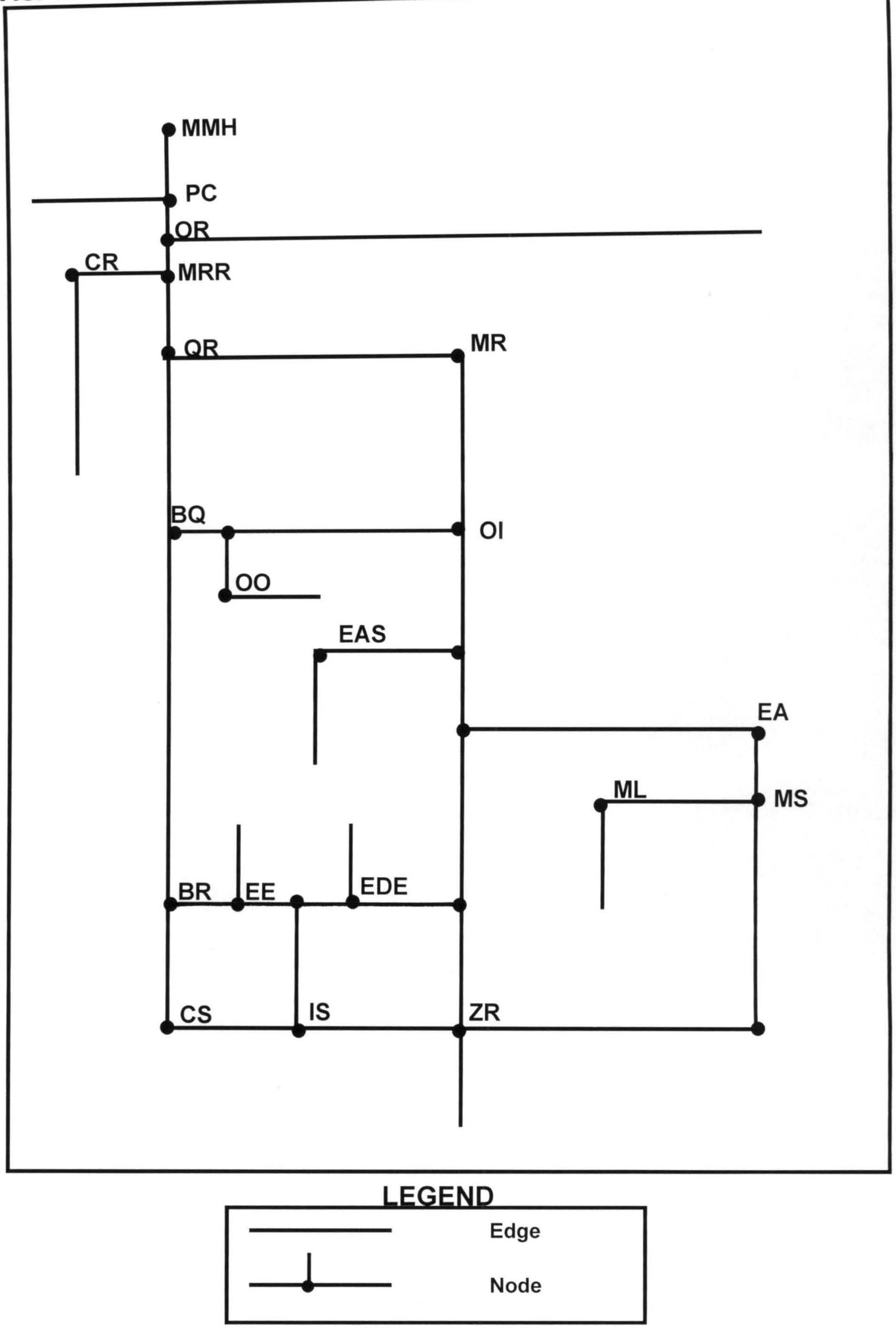
Using the topological map of Calabar Municipality road network; shown as Fig. 4.2, the network matrix for Calabar Municipality (Appendix B) was deduced, and the alpha index is calculated for the area based on the sampled roads. They are as follows:-

TABLE 4.2 **THE SAMPLED ROADS**

| NAME OF ROAD | CODE |
|---|---|
| Marian Road | MR |
| Marian Road | MRR |
| Eta Agbo Street | EA |
| Barracks Road | BR |
| Eyo Etta Street | EE |
| Cameroon Street | CS |
| Zoo Road | ZR |
| Murtala Mohammad Highway | MMH |
| Old Ikang Road | OI |
| Old Odukpani Road | OR |
| Quarry Road | QR |
| Port Complex Road | PC |
| Club Road | CR |
| Big Qua Town Road | BQ |
| Oroko Odo Street | OO |
| Eyo Aikpo Street | EAS |
| Edem Ekpeyong Street | EDE |
| Mbora Street | MS |
| Mbora Lane | ML |
| Itu Street | IS |

**Source: Author's Sampling, January 2001**

FIG. 4.2: TOPOLOGICAL MAP OF CALABAR MUNICIPALITY ROAD NETWORK



The alpha index for the network in Fig. 4.2, using the formula provided in section 3.2.3 is 29.7%; approximately 30% (see mathematical details in Appendix C).

This means that the urban road network of Calabar Municipality has 30 per cent of the possible maximum number of circuits.

### 4.1.2 BETA INDEX OF CALABAR MUNICIPALITY

The beta index of Calabar Municipality is necessary for describing the network structure and its connectivity.

Using the topological map of Calabar Municipality road network (Fig. 4.2), it can be obtained that the total number of edges on the network is 39, whereas the total number of nodes on the network is 26. So, by application of the formula for beta index provided in section 3.2.3, the beta index for Calabar Municipality is 1.5 ( See mathematical details in Appendix C).

This means that the urban road network of Calabar Municipality is complex and contains more than one circuit.

## 4.2 ACCESSIBILITY OF CALABAR MUNICIPALITY

The network matrix compiled for Calabar Municipality (Appendix B), shows the number of edges separating various nodes. The total accessibility for Calabar Municipality from the network matrix is 1, 701, while the total number of edges on Fig. 4.2 is 39 and the total number of nodes is 26.

The mean shimbel index for Calabar Municipality is therefore 65.4; approximately 65. (See mathematical details in App. C.).

From the foregoing, a high accessibility index of 1,701 implies that the urban road network of Calabar has a low degree of accessibility, and a Shimbel index of about 65 for Calabar Municipality implies that 65 edges or routes are required to link all other nodes in the town before maximum accessibility can be attained.

Also inferred from the data sets and analysis it that, Big Qua Town Road is the most accessible road in Calabar Municipality; with a Shimbel index of 62, while Murtala Mohammed Highway is the least accessible; with a Shimbel index of 121 and on the account of its disconnected links.

The road plan efficiency of Calabar Municipality road network, is therefore shown by its connectivity and accessibility.

## 4.3 FACTORS RESPONSIBLE FOR THE NETWORK STRUCTURE.

Transportation is a spatial process; it takes up space and time. A spatial process, then involves change within some or all of the elements of a system. in a given time period. It is used to 'explain' spatial structures and patterns. as it refers to a causal chain of events that produces change over time in the land use pattern. A pattern existing at one moment of time is the result of the operation of processes that have had different impacts (Muller and Wheeler, 1986).

Initially, prior to the Colonial era, trekking and head poterage were the dominant modes of transportation overland owing to available minor (unpaved) paths and lack of motorized transport modes. During the Colonial era, only areas of raw materials (minerals) extraction and high agricultural production were linked by roads. Then, following independence, more areas were linked by good roads for administration reasons. With the development of industrial estates for socio-economic gains, proper access roads were developed to link them. Then, as the communal pressure for development and adequate access grew, the road network expanded.

This attempt to 'explain', in order to unravel the varied spatial processes (factors) which have acted in the past and continue to act in the present to produce the road network structure is hence focused on the structural.

Prior to the development of the existing road network in Calabar Municipality, residential densities were high in very few locations surrounding the Watt-market than other parts of the city. The good quality road network in that part of the city attracted transport operators to restrict their services to that area. Hence, there was a concentration of good well accessible and connected road network there; with a high population and high demand for goods and services, there was incentive for a high concentration of economic activities in the area. On the other hand, the absence of good road network linking the Watt-market area (CBD) with the city periphery increased the friction of distance between it and other parts of the city.

For instance, in the early 1960s, road network and quality decreased with distance way from the CBD to minor ( unpaved) roads in the residential suburbs. Further away, isolated settlements at the urban periphery were lined by minor footpaths.

The poor condition of the roads in the residential suburbs made traveling from that part of the city to another, strenuous due to the high cost of travel measured in terms of time and money required for such journeys.

After 1967, when Calabar became the capital of Cross River State, growth in the urban road network set in. The development in the road network concentrated and expanded from the already developed built-up areas to the residential peripheries of Edim Otop and Ikot Ansa. This influenced the incidence and concentration of economic activities like banking, retail trading, and other commercial functions in other emerging centers such as the Calabar Road – Mary Slessor Avenue Node and the Marian Road – Quarry Road Node. Also, this improved transportation system between the residential suburbs and the C.B.D.

From the foregoing, there is a pointer to the fact that, urban road development has continued in Calabar Municipality over the years. Since after independence based on a complexity of interrelated processes.

From available data for the period of study (i.e. 1972 to 1991), the rate of urban road development is calculated using the formula provided in section 3.2.3.

Hence, the rate of road development in the study area from data presented in Appendix A is 32.5% (see mathematical details in App. C)

This means that the rate of urban road development in Calabar Municipality for the period (1972 to 1991) is low; with an average of abut 1.1 kilometers of urban road construction per year.

Invariably, this points to the fact that, the network density in the terminal year (1991) is higher than the networks density in the reference year (1972). However, this can be confirmed by the network density statistic for Calabar Municipality, using the formulae provided in section 3.2.3, the density of road network in Calabar municipality for 1972 is 0.68 Km /unit area, whereas the density of road network in Calabar Municipality for 1991 is 0.9Km/Unit area ( see mathematical details in Appendix C).

Form these statistics, it is obvious that the number of urban roads in the study area has increased over the period under study.

## 4.3.1 **<u>DEGREE OF DEVELOPMENT OF CALABAR MUNICIPALITY ROAD NETWORK</u>**

The degree of development or <u>extent</u> of a network can be effectively measured by the pie (II) index. It compares the total length of a network (c) with the network diameter (d) as stated in section 3.2.3

For the network under study; in 1972 the pie index is 5.84, whereas in 1991 the pie index obtained is 7.75 (see mathematical details in Appendix C).

From the indices, it implies that the degree of development of the network has increased over the period under study; though; it is quite low as representative of a developing region.

## 4.4 **<u>VARIATIONS IN ROAD TYPE AND ROAD TRAFFIC FACILITY</u>**

This factor plays the most crucial role in the movement of traffic and therefore should be paid utmost attention in the efforts to provide efficient flows of traffic in the city's road network.

It has been observed that the smooth flow of traffic in cities highly depends on the provision of some facilities along the roadsides. These include traffic signs and signals, sidewalks and pedestrian crossings, off-street parking spaces and streetlights. But in the study area, such facilities are either lacking, inadequately provided or dilapidated. This is shown in table 4.3:

TABLE 4.3 **TYPE AND CONDITION OF ROAD TRAFFIC FACIILITY**

| LOCATION (NAME OF ROAD) | TYPE OF FACILITY | | | | | | CONDITION/ REMARKS |
|---|---|---|---|---|---|---|---|
| | Traffic Sign | Traffic Signal | Side walk | Pedestrian crossing | Off-Street Parking Space | Street Light | |
| Marian Road | √ | – | - | √ | - | - | Traffic Sign inadequate |
| Marina Road | √ | – | - | - | - | √ | Streetlights non-operational |
| Eta Agbo Street | √ | √ | – | √ | - | √ | Traffic Signal non - operational |
| Barracks Road | √ | - | - | - | - | - | Traffic Sign inadequate |
| Eyo Etta Street | – | - | - | - | - | - | - |
| Cameroon Street | √ | - | - | - | - | √ | Streetlights epileptic |
| Zoo Road | - | - | - | - | - | - | - |
| Murtala Mohammed Highway | √ | √ | √ | √ | √ | √ | Traffic Signal non-operational |
| Old Ikang Road | √ | - | - | √ | - | √ | Streetlights epileptic |
| Old Odukpani Road | √ | - | - | √ | - | - | Pedestrian Crossing abandoned |
| Quarry Road | √ | - | - | √ | - | √ | Streetlights epileptic |
| Port Complex Road | √ | - | - | - | - | √ | Traffic Sign inadequate |
| Club Road | √ | - | - | √ | - | √ | Streetlights epileptic |
| Big Qua Town Road | √ | - | - | √ | - | - | Traffic sign inadequate |
| Orok Odo Street | - | - | - | - | - | - | - |
| Eyo Aikpo Street | - | - | - | - | - | - | - |
| Edem Ekpeyong Street | - | - | - | - | - | - | - |
| Mbora Street | - | - | - | - | - | - | - |
| Mbora Lane | - | - | - | - | - | - | - |
| Itu Street | - | - | - | - | - | - | - |

**Source:** **Author's fieldwork, January, 2001**

Also of great importance to the free flow of traffic in the urban road network is the type and width of roads. Most urban roads in Nigeria are quite narrow especially at intersections or road nodes (junctions). In Calabar Municipality, the greater parts of the road network which were built in the colonial era through the early years of independence are too narrow. So, today, most of the roads in the C.B.D such as Calabar Road, Goldie Street and Garden Street are found to be less than the desired standard in terms of the width capacity. Coupled with the characteristic roadside parking, owing to the absence of off-street parking spaces and the sidewalks for pedestrians, these streets are mostly restricted to accommodate unidirectional traffic flow to ease congestion.

# CHAPTER 5

# SUMMARY AND CONCLUSIONS

The urban road development in Calabar Municipality as gathered from this research is at a slow rate; the extent of the network is quite low and the structure of the network is complex; though far below the maximum possible number of connections. In addition, the urban road network in the municipality has a low degree of accessibility.

Concentration of roads were found to occur largely in the old C.B.D., where most of the roads are quite narrow, especially at the junctions. Also, it was gathered that the level of urban road development and provision of road traffic facility have not been sufficient enough to ease the congestion of traffic on some roads and equally cater for future developments in an export processing zone. Infact, the municipality has continued to develope without a corresponding provision, maintenance or improvement in the road traffic facilities.

It is clear that, the structure of the urban road network in Calabar municipality is a product of different processes and approaches to city development by the authorities. These processes and approaches were made within structural sociopolitical and economic constraints; all of which interacted in unrelated ways. The provision and maintenance of adequate road traffic facilities (such as off-street parking facilities) will help reduce the risk of accidents and improve on the problems of commuting experienced by some residents of the municipality. Therefore, it is absolutely essential that the public authority should provide adequate road traffic facilities for the complex and poorly connected road structure and equally ensure strict utilization and maintenance of these facilities.

Furthermore public authority should gain complete control of the process of urban structural development, in order for the construction and maintenance of these roads to be methodically built into the master plan and transportation plan of the municipal government.

Attempts should be made towards the incorporation of relevant inputs from all authorities concerned with urban development, systematically, in order to produce an efficient system of urban road network that will enhance smooth interaction between the diverse land use zones in the city.

From all the above, the results show that it is possible to apply aerial photography to urban road development by remote sensing techniques. Equally, remote sensing as this research has explained, does not only apply to evaluating or assessing urban road development; or studies in transportation geography, but offers a significant opportunity to help improve the effectiveness of urban management.

It helps guide urban growth and development, and equally helps to maintain and improve the quality of metropolitan environments.

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## APPENDIX A: LENGTH OF ROADS IN CALABAR MUNICIPALITY (1972 AND 1991)

| S/N | NAME OF ROAD | LENGTH (KM) 1972 | (KM) 1991 |
|---|---|---|---|
| 1 | Marian Road | 5.10 | 5.70 |
| 2 | Spring Road | 1.80 | 1.80 |
| 3 | Marina Road | 3.00 | 3.00 |
| 4 | Goldie street | 2.63 | 4.20 |
| 5 | Eta Agbo street | 1.98 | 2.10 |
| 6 | Akim Road | 2.22 | 2.40 |
| 7 | Barracks Road | 1.88 | 2.34 |
| 8 | Leopard Town road | 0.65 | 1.35 |
| 9 | Eyo Etta street | 0.51 | 0.51 |
| 10 | Otop Abasi street | 0.54 | 0.54 |
| 11 | Cameroon street (Mary Slessor Avn.) | 1.28 | 1.29 |
| 12 | Bokobiri street | 0.21 | 0.48 |
| 13 | Zoo Road | 0.49 | 0.51 |
| 14 | Ediba Road | 2.33 | 3.15 |
| 15 | Murtala Mohammed H. way | 7.35 | 11.4 |
| 16 | New Ikang Road | 4.35 | 7.44 |
| 17 | Old Ikang Road | 1.05 | 1.17 |
| 18 | Mekenge Layout street | - | 1.59 |
| 19 | Old Odukpani road | 6.60 | 7.95 |
| 20 | Atekong Drive | 1.20 | 1.53 |
| 21 | Quarry (MCC) Road | 3.48 | 7.56 |

| | | | | |
|---|---|---|---|---|
| 22 | Industry Road | 1.85 | 2.25 | |
| 23 | Port Complex Road | 3.80 | 4.38 | |
| 24 | Moore road | 0.93 | 0.93 | |
| 25 | Club Road | 0.48 | 0.48 | |
| 26 | Nyok Esu street | 0.53 | 0.54 | |
| 27 | Big Qua town road | 0.93 | 0.93 | |
| 28 | Oqua street | 0.30 | 0.30 | |
| 29 | Orok Odo street | 0.16 | 0.18 | |
| 30 | Okoro Agbo street | 0.97 | 0.99 | |
| 31 | Eyo Aikpo street | 0.40 | 0.42 | |
| 32 | Eteta Ita street | 0.50 | 0.60 | |
| 33 | Edem Ekpeyong street | 0.45 | 0.48 | |
| 34 | Adazi street | 0.33 | 0.33 | |
| 35 | Mbora street | 0.66 | 0.66 | |
| 36 | Abang Aseng street | 0.54 | 0.54 | |
| 37 | Mbora Lane | 0.38 | 0.42 | |
| 38 | Esuk Atu Road | 1.88 | 2.25 | |
| 39 | Itu street | 0.24 | 0.24 | |
| 40 | Edem Odo street | 0.32 | 0.32 | |
| | **TOTAL** | **64.3** | **85.25** | |

**Source**: Air photos and photomaps of Calabar; 1972 and 1991.

## APPENDIX B: NETWORK MATRIX OF CALABAR MUNICIPALITY

| | MR | MRR | EA | BR | EE | CS | ZR | MMH | OI | OR | QR | PC | CR | BQ | OO | EAS | EDE | MS | ML | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Marian Road | 0 | 2 | 4 | 4 | 5 | 5 | 5 | 5 | 1 | 3 | 1 | 4 | 3 | 2 | 3 | 3 | 5 | 5 | 6 | 6 |
| Marina Road | 2 | 0 | 6 | 3 | 4 | 4 | 6 | 3 | 3 | 1 | 1 | 2 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 5 |
| Eta Agbo street | 4 | 6 | 0 | 6 | 5 | 5 | 3 | 9 | 3 | 7 | 5 | 8 | 7 | 5 | 5 | 3 | 3 | 1 | 2 | 4 |
| Barracks Road | 4 | 3 | 6 | 0 | 1 | 1 | 3 | 6 | 3 | 4 | 2 | 5 | 4 | 1 | 3 | 5 | 3 | 5 | 6 | 2 |
| Eyo Etta street | 5 | 4 | 5 | 1 | 0 | 2 | 4 | 7 | 4 | 5 | 3 | 6 | 5 | 2 | 4 | 6 | 2 | 6 | 7 | 2 |
| Cameroon Street | 5 | 4 | 5 | 1 | 2 | 0 | 2 | 7 | 4 | 5 | 3 | 6 | 5 | 2 | 4 | 6 | 4 | 4 | 5 | 1 |
| Zoo Road | 5 | 6 | 3 | 3 | 4 | 2 | 0 | 9 | 4 | 7 | 5 | 8 | 7 | 4 | 6 | 4 | 2 | 2 | 3 | 1 |
| Murtala Muhammed H.way | 5 | 3 | 9 | 6 | 7 | 7 | 9 | 0 | 6 | 2 | 4 | 1 | 4 | 5 | 7 | 8 | 9 | 10 | 11 | 8 |
| Old Ikang Road | 1 | 3 | 3 | 3 | 4 | 4 | 4 | 6 | 0 | 4 | 2 | 5 | 4 | 2 | 2 | 2 | 4 | 4 | 5 | 5 |
| Old Odukpani Road | 3 | 1 | 7 | 4 | 5 | 5 | 7 | 2 | 4 | 0 | 2 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 6 |
| Quarry Road | 1 | 1 | 5 | 2 | 3 | 3 | 5 | 4 | 2 | 2 | 0 | 3 | 2 | 1 | 3 | 4 | 5 | 6 | 7 | 4 |
| Port Complex Road | 4 | 2 | 8 | 5 | 6 | 6 | 8 | 1 | 5 | 1 | 3 | 0 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 7 |
| Club Road | 3 | 1 | 7 | 4 | 5 | 5 | 7 | 4 | 4 | 2 | 2 | 3 | 0 | 3 | 5 | 6 | 7 | 8 | 9 | 6 |
| Big Qua Town Road | 2 | 2 | 5 | 1 | 2 | 2 | 4 | 5 | 2 | 3 | 1 | 4 | 3 | 0 | 2 | 4 | 4 | 6 | 7 | 3 |
| Orok Odo street | 3 | 4 | 5 | 3 | 4 | 4 | 6 | 7 | 2 | 5 | 3 | 6 | 5 | 2 | 0 | 4 | 6 | 6 | 7 | 5 |
| Eyo Aikpo street | 3 | 5 | 3 | 5 | 6 | 6 | 4 | 8 | 2 | 6 | 4 | 7 | 6 | 4 | 4 | 0 | 4 | 4 | 5 | 5 |
| Edem Ekpeyong Street | 5 | 6 | 3 | 3 | 2 | 4 | 2 | 9 | 4 | 7 | 5 | 8 | 7 | 4 | 6 | 4 | 0 | 4 | 5 | 2 |
| Mbora Street | 5 | 7 | 1 | 5 | 6 | 4 | 2 | 10 | 4 | 8 | 6 | 9 | 8 | 6 | 6 | 4 | 4 | 0 | 1 | 3 |
| Mbora Lane | 6 | 8 | 2 | 6 | 7 | 5 | 3 | 11 | 5 | 9 | 7 | 10 | 9 | 7 | 7 | 5 | 5 | 1 | 0 | 4 |
| Itu Street | 6 | 5 | 4 | 2 | 2 | 1 | 1 | 8 | 5 | 6 | 4 | 7 | 6 | 3 | 5 | 5 | 2 | 3 | 4 | 0 |
| **Total** | | | | | | | | | | | | | | | | | | | | |

Source: Author's fieldwork and Calabar Municipality Base Map, January 2001.

**APPENDIX C**

**ALPHA INDEX OF CALABAR MUNICIPALITY**

Using the formulae: $\dfrac{(e-n)+1}{2n-5}$

where $e = 39$

and $n = 26$

hence, the alpha index for Calabar Municipality is :

$$\frac{(39-26)+1}{52-5}$$

$= 29.7 \gtrsim 30$

in percentage = 30%

**BETA INDEX OF CALABAR MUNICIPALITY**

Using the formulae: $\beta = \dfrac{e}{n}$

Where e (total number of edges) = 39

and n (total number of nodes) = 26

hence, the beta index for Calabar Municipality is:

$$\frac{39}{26}$$

$= 1.5$

**SHIMBEL INDEX OF CALABAR MUNICIPALITY**

Using the formulae: $\text{Shimbel index} = \dfrac{\text{Total accessibility}}{\text{Number of nodes}}$

Where the total accessibility = 1,701

and the number of nodes = 26

Hence, the Shimbel index for Calabar Municipality is:

$$\frac{1,701}{26}$$

$$= 65.4$$

$$\approx \underline{65}$$

## RATE OF ROAD DEVELOPMENT OF CALABAR MUNICIPALITY

Using the formulae: $\frac{B - A}{A} \quad X \quad 100$

Where $A = 64.3Km$

and $B = 85.25Km$

Hence, the rate of road development of Calabar Municipality is:

$$= \frac{85.25 - 64.3}{64.3} \quad X \quad 100$$

$$= \underline{32.5\%}$$

## NETWORK DENSITY STATISTIC OF CALABAR MUNICIPALITY

Using the formulae: $D = \frac{L}{A}$

Where L = 64.3Km (1972) and 85.25Km (1991)

and A = $94.77Km^2$

Hence, the road network density of Calabar Municipality for

1972 is: $\frac{64.3}{94.77} = \underline{0.68Km / Unit\ area}$

Whereas, the road network density of Calabar Municipality

For 1991 is: $\frac{85.25}{94.77} = \underline{0.90Km / Unit\ area}$

**DEGREE OF DEVELOPMENT OF CALABAR MUNICIPALITY ROAD NETWORK**

Using the formula for pie ($\pi$) index: $\pi = \frac{c}{d}$

where C = 64.3Km (1972) and 85.25Km (1991)

and d = 11 (1972 and 1991)

Hence, the degree of road network development in Calabar Municipality in 1972 is:

$$\frac{64.3}{11} = \underline{5.84}$$

Whereas, in 1991, the degree of road network development in Calabar Municipality is:

$$\frac{85.25}{11} = \underline{7.75}$$